Electricity Sector Externalities

Introduction

The June 13, 2003 meeting of the Renewable Energy Modelers' Working Group will include presentations and discussion of how national energy and environmental forecasting models might be improved by using data on non-market and other unrecognized costs and benefits to society of renewable electricity generation. Such improvements could help public officials assess overall costs and benefits of different scenarios for the growth of renewable electricity.

Markets for different goods and services in the economy don't take into account the full set of societal costs and benefits. Some of these costs and benefits are true externalities - side effects of market decisions that primarily impact third parties and do not directly influence market behavior. Others are unrecognized attributes of the product, characteristics that could be accounted for in the market, but may not be at present. Externalities from electricity generation include air pollution, greenhouse gases, water use and water quality impacts, land use impacts, and economic development impacts. Unrecognized costs and benefits from electricity generation might include price volatility, which could be accounted for in markets if different electricity products with different price volatility were available, and some elements of distributed generation value.

Market prices are a readily available, quantitative measure of the value of goods that are traded. However, when there are limited or non-existent markets for socially valuable items, such as clean air, there is no market price and assigning a quantitative value is such a challenge, requiring choices among alternative methods and subjective judgements. This document provides a brief overview of quantification of selected environmental externalities.

The following sections of this document contribute to the discussion of whether such non-market and unrecognized benefits and costs could be incorporated into models, considering three questions:

- Which non-market and unrecognized costs and benefits are important?
- How can these effects be quantified? The case of environmental externalities.
- How could quantitative measures of non-market or unrecognized costs and benefits be used in analysis of opportunities for renewable electricity generation?

Following these three sections, an annotated bibliography provides additional references.

Which non-market effects are important?

The following tables catalogue some of the potential non-market effects of renewable electricity generation. Table 1 summarizes a number of the unrecognized market benefits and the non-market benefits of various renewable energy technologies. It also lists the existing markets the technologies can serve. A few approximate values are noted, with references. The distributed generation values presented are described in greater detail in Table 2, and the hedge value is taken from Table 3. The tables illustrate the scope and potentially significant value of the unrecognized and non-market benefits of renewable energy technologies.

Table 1. Summary of Unrecognized or Non-Market Benefits of Renewable Energy Technologies

Technology	Markets	Environmental Impacts (cents/kWh) [1]	DG Value (cents/kWh) (see also table 2)	Hedge Value (cents/kWh)[2] (see also table 3)	Import Premium (cents/kW)[3]	Employment (Jobs/MW)[4]
Direct Solar	Heating markets	✓	✓	✓	✓	✓
Wind Generation	Wholesale electric market	0.3	0	0.5	0.2	14
Biomass Generation	Wholesale electric market	0.3	0	0.5	0.2	20
Biofuels	Fuels markets	✓	✓	✓	✓	✓
Building Integrated Photovoltaics	Retail electric market	0.3	✓	0.5	0.2	✓
Direct Geothermal	Heating markets	✓	✓	✓	✓	✓
Geothermal Generation	Wholesale electric market	0.3	0	0.5	0.2	26

✓ = These are likely to have value, but a quantitative estimate from the literature has not been identified.

Table 2 summarizes the categories and ranges of values for distributed generation, which can include some renewable generation technologies, particularly building integrated photovoltaics and small wind.

Table 2. Estimated Value of Distributed Generation

Item	**Description**	**Estimated Value** ($/kW-year)
Electric Energy Value	Direct market value	100 - 150
Thermal Energy Value	Direct market value	100 - 150
Option Value	Value of option of rapidly building small amounts of electric generating capacity.	50-200
Deferral Value	Value of deferring infrastructure investments such as transmission and distribution upgrades.	50-200
Engineering Cost Savings	Value of reducing operations and maintenance costs of transmission and distribution system. Includes reduced losses, voltage support, balancing reactive power, extending equipment life.	50-175
Customer Reliability Value	Value of reduced outages for customer.	25-250
Environmental Value	Value of reduced emissions available from some distributed generation technologies.	Not estimated[5]
Source: J. Swisher, 2002. Cleaner Energy, Greener Profits: Fuel Cells as Cost-Effective Distributed Energy Resources.		

[1] Adapted from Ottinger R.L; Wooley, D.R.; Rovinson, N.A.; Hodas, D.R.; Babb, S.E. (1990). Environmental Costing of Electricity. Oceana Publications: New York, NY.
[2] Bolinger et al. (2002). Table 1, page 31, lists externality costs for coal-fired units. This value is below the estimate for New Source Performance Standards and above what is expected for advanced coal technologies.
[3] Adapted from Leiby, P., D.W. Jones, T. R. Curlee and R. Lee, 1997. *Oil Imports: An Assessment of Benefits and Costs*, Oak Ridge National Laboratory, Report ORNL-6851, online version at http://pzl1.ed.ornl.gov/ORNL6851.pdf. This represents value of avoiding oil imports, including excess cost of oil due to the producers' monopoly and the direct and macroeconomic costs of oil price spikes. It is calculated from an estimated import premium of $1.30/barrel of oil, where estimates range from $0 to $10 or more per barrel, and does not address the relatively small and declining role of oil within the electric sector.
[4] Roberts, P.A.; Harrison, I.S.; Reinertsen, J.L.; Margolis, M. (1995). An Assessment of the Economic and Employment Impacts of the Commercialization of Renewable Technologies in Washington/Oregon. Second Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. August 21-24, 1995. Portland, Oregon. NREL/CP-200-8098 DE95009230.
[5] Swisher states, "The environmental benefit of fuel cells' low emission rate is unlikely to be realized directly, but it makes fuel cells easier to site than other DG, and this can reduce both lead-time and financial risk." This statement would also apply to clean renewable distributed generation, such as solar photovoltaics.

Table 3 summarizes categories and relative magnitude of risk associated with renewable vs. natural gas electricity generation. Most renewable electricity generation sources (with the exception of some biomass technologies) offer the benefit of price stability over time, because they have no fuel costs. Most of the costs are associated with capital and construction expenditures that occur up-front and are known over the lifetime of the project. In contrast, the price of natural gas is volatile and future prices are unknown. Fuel price swings can have a large impact on generation costs. Estimates of the cost of fuel price risk are listed in Table 3. Other types of risk are qualitatively, not quantitatively, compared.

Table 3. Comparison of Fuel Price and Other Risks Associated with Natural Gas and Renewable Energy Generation

Item	Description	Relative Magnitude of Risk
Fuel Price Risk	Risk of volatility in electricity prices caused by fuel price changes.	NG > RE (costs 0.5 cents/kWh to mitigate NG fuel price risk)
Fuel Supply Risk	Risk of unreliable electricity generation caused by fuel supply disruptions.	NG > RE for systematic and catastrophic interruptions RE > NG for "normal" variations in supply
Performance Risk	Risk of electricity supplier not meeting contractual obligations.	NG ≅ RE
Demand Risk	Risk of demand mismatch with supply.	RE > NG
Environmental Risk	Risk of environmental liability under current or future regulations.	NG > RE
Regulatory Risk	Risk of unforeseen cost due to new regulations.	NG ≅ RE
Source: Bachrach, D.; R. Wiser; M. Bolinger; W. Golove (2003). Comparing the Risk Profiles of Renewable and Natural Gas Electricity Contracts: A Summary of the California Department of Water Resources Contracts.		

How can these effects be quantified? The case of environmental externalities.

Environmental externalities are one type of non-market benefit of renewable electricity generation identified above, and are a topic for discussion at the June 13, 2003 Renewable Energy Modelers' Working Group. Therefore, this section focuses on methods for quantifying externalities associated with air emissions from electricity generation.

Air emissions from electricity generation impose costs upon society ranging from ecological effects to human health effects. Society reduces these costs through air emissions regulations, including some market-based approaches. The emissions that remain after the regulations take effect still can impose costs. Renewable electricity generation benefits society by reducing these emissions.

This section offers two examples of information that may help quantify environmental externalities: 1) EPA findings on environmental externalities of electricity generation, and 2) methods that Public Utilities Commissions have used to value externalities during planning of electricity generation expansion.

EPA Findings on Environmental Externalities

The EPA 2003 Strategic Plan (http://www.epa.gov/ocfo/plan/2003sp.pdf, March 5, 2003 version) provides an overview of social benefits and costs of EPA activities. Data underlying this plan may support some quantification of externality analysis. The plan compiles quantitative estimates of costs and benefits of five major goals: Clean Air, Clean and Safe Water, Protect and Restore the Land, Healthy Communities and Ecosystems, and Environmental Stewardship. Among these goals, clean air relates most directly to the electricity sector. [6] Costs and benefits of the Clean Air Act are quantified in a series of studies, the "Section 812" studies. Based on the Section 812 prospective study, the single point estimates for 2002 for the Clean Air Act Amendments were $30 billion in costs and $119 billion in benefits (Strategic Plan, Appendix 1, p.7). This might suggest that society could reap greater benefits by paying more for pollution control, although the limitations and uncertainty of these estimates should be considered before drawing this type of conclusion. Electric utility point sources account for $5 billion (direct costs) of the $30 billion, but the proportion of benefits attributable to emissions control at electric utilities is not presented. (Section 812 studies are completed within EPA's Office of Policy Analysis and Review.)

In addition to the Section 812 studies, EPA performs Regulatory Impact Analyses (RIAs) of individual air quality regulations.[7] These RIAs quantify costs and benefits of some proposed regulatory actions. RIAs that include assessments of alternatives more stringent than the actual regulation are useful in estimating externalities, because they indicate how much cost the remaining emissions will continue to impose on society. Table 4 lists RIAs for recent air quality regulations that affect electricity generators. The monetized values included in this table are rough estimates, and the RIAs describe their limitations, notably the exclusion of many costs and benefits. Table 5 shows monetized values for different ozone and PM 2.5 standards, shown separately to provide more detail.

Table 4. Estimates of Benefits and Costs of Reducing Air Pollution from Various EPA RIAs

Reference	Regulation Included in 812 Prospective?	Assesses More Stringent Regulation?	Comments

Regulatory Impact Analysis for the NOx SIP Call, FIP, and Section 126 Petitions (September, 1998, EPA-452/R-98-0003)	812 includes preliminary, not final, form of regulation.	Yes	For more stringent 0.12 lb/mmBtu emissions rate in 2007 (1990$):
			cost = $2.1 billion;
			benefit = $2.9 to $5.5 billion
			For 0.15 lb/mmBtu (actual level implemented)
			cost = $1.7 billion;
			benefit = $1.1 to $4.2 billion
			(Vol. 2, p. 5-1 to 5-2)

Regulatory Impact Analysis for the Final Section 126 Petition Rule (December 1999)	812 includes preliminary, not final, form of regulation.	No	For 0.15 lb/mmBtu emissions rate in 2007 (1997$): cost = $1.2 billion benefit = $0.9 to $1.4 billion (p. 12-4)
Regulatory Impact Analyses for the Particulate Matter and Ozone National Ambient Air Quality Standards and Proposed Regional Haze Rule (July 1997)[8]	Not included in 812 study.	Yes	See Table 5.

[6] For example, one estimate is that land and water impacts would account for 10% of the externality costs for a coal-fired power plant that met New Source Performance Standards, with air emissions accounting for 90%. [R. L. Ottinger; D.R. Wooley; N.A. Robinson; D.R. Hodas; S.E. Babb (1990). Environmental Costs of Electricity. New York: Oceana Publications.]

[7] A good overall authority on the RIA process is the Office of Air Quality Planning and Standards, Innovative Strategies and Economics Group. For example, their "Economic Analysis Resource Document" offers an overview of economic analysis within EPA, including RIAs. See http://www.epa.gov/ttnecas1/econdata/Rmanual2/1.0.html.

[8] Regulatory Impact Analyses for the Particulate Matter and Ozone National Ambient Air Quality Standards and Proposed Regional Haze Rule (July 1997), pp. 13-3 to 13-4.

Table 5. Incremental Costs of Implementation of New PM2.5 and Ozone Standards
(Values are billions of 1990$ in 2010)

Extent of Implementation ➜	**Partial Implementation**		**Full Implementation**	
➘ Form of Standard	**Cost**	**Benefit**	**Cost**	**Benefit**
PM 2.5 Standard: 15 μg/m³ 24-hour 50 μg/m³ annual (high end estimate of value)	$9.4	$108		
PM 2.5 Standard: 15 μg/m³ 24-hour 65 μg/m³ annual	$8.6	$19 - 104	$37	$20 - $110
PM 2.5 Standard: 16 μg/m³ 24-hour 65 μg/m³ annual (high end estimate of value)	$5.5	$90		
Ozone Standard: 0.8 ppm 3rd max. (high end)	$1.4	$2.9		
Ozone Standard: 0.8 ppm 4th max.	$1.1	$0.4 – $2.1	$9.6	$1.5 – $8.5
Ozone Standard: 0.8 ppm 5th max. (high end estimate of value)	$0.9	$1.6		
1.0 Deciview Improvement Over 15 Year	$2.1	$1.3 – $3.2		
1.0 Deciview Improvement Over 10 Years	$2.7	$1.7 – $5.7		

Public Utility Commission Environmental Externalities Estimates

A second source of information that may help quantify environmental externalities is the assessment of emission effects that Public Utilities Commissions (PUC) in many states considered in electricity generation resource expansion. The PUCs' approaches to externality estimates differ according to the types of externalities selected for consideration, the quantification techniques used, and the manner in which the externality estimates are used in decisions. The PUCs' methods, the lessons learned about challenges in quantifying environmental externalities, and the values themselves all may be useful to future analytic efforts.

Several reports from the early to mid 1990s summarize monetized values of environmental externalities that were considered for use in state integrated resource planning. Seven states developed monetized environmental externality values: California, Massachusetts, Nevada, New York, Wisconsin, Oregon, and Minnesota (EIA 1995). Subsequently, many states have restructured their electricity markets and moved away from the consideration of environmental externalities in resource planning. Of the seven states that developed monetized externality values, only Wisconsin and Minnesota have maintained traditionally regulated electricity markets (http://www.eia.doe.gov/cneaf/electricity/chg_str/regmap.html). The current status of environmental externality considerations within resource planning in each of these states is unknown.

Table 6. Sample Monetized Environmental Externalities Adders (cents/kWh, $1992)

	California	Massachusetts	Nevada	New York	Wisconsin
Coal – pulverized	2.2	4.0	4.0	0.6	1.7
Coal - AFB	1.7	3.7	3.6	0.3	1.8
Coal - IGCC	1.0	2.5	2.5	0.2	1.4
Natural Gas - CC	0.7	1.5	1.4	0.1	0.7
Natural Gas – CT	1.1	2.4	2.4	0.2	1.2
Wood – Steam	1.9	5.2/0.9	4.8/0.7	0.3/0.1	2.7/0.1
Biomass – Advanced Gasification	1.2	3.0/0.3	3.0/0.3	0.2/0.1	1.7/0.1
Municipal Solid Waste	1.8	4.9	4.7	0.3	2.2
Landfill Methane	1.7	3.2/-2.8	3.0/-2.9	0.4	1.0/-2.7
Geothermal – Flashed Steam	<0.1	NA	<0.1	NA	NA
Solar – Trough with Gas Backup	0.7	NA	1.8	NA	NA

Sources:
Swezey, B. G.; Porter, K. L.; Feher, J. S. (1994). “Potential Impact of Externalities Considerations on the Market for Biomass Power Technologies. Report No. TP-462-5789. National Renewable Energy Lab, Golden, Colorado.

Energy Information Administration (1995). “Electricity Generation and Environmental Externalities EIA Externalities report: Case Studies.” DOE/EIA-0598. Department of Energy, Washington, D.C.
http://www.eia.doe.gov/cneaf/electricity/external/external.pdf

How could these quantitative measures be used in analysis of opportunities for renewable electricity generation?

This final section offers thoughts on how quantitative measures of the non-market effects of renewable electricity might be used in national energy and environmental forecasting models.

1. Models or modeling runs that seek to represent market behavior would not include externalities, unless there is a mechanism by which they are assumed to affect market behavior. That’s because externalities are, by definition, factors that are not considered in market decisions. Therefore, identification and quantification of non-market effects and externalities is most relevant to modeling that explores social costs and benefits of future energy and environmental scenarios, not just expected market behaviors.

2. Quantifying relevant environmental externalities over the time horizons in forecasting models is a challenge because it requires a quantitative estimate of residual environmental effects after full implementation of existing and new environmental regulation, valuation of those effects, and estimates of the cost of prevention or mitigation.

3. Valuation of non-market costs and benefits is necessarily more subjective, and different individuals and groups disagree about monetary values. Thus transparency in data sources and sensitivity analyses or other methods that acknowledge the range of possible values are especially important in analytic efforts seeking to incorporate externalities.

The Renewable Energy Modeling Summit will provide opportunity for discussion of these and other issues and will identify approaches and challenges for using quantitative measures of non-market and unrecognized costs and benefits in analyses of renewable electricity generation.

Annotated Bibliography

This is based on literature searches of selected databases during Fall 2002.

Integrated assessments of economic and environmental effects of advanced energy technologies have been considered in a number of studies:

Finch, E. F. (1994). "The Uncertain Role of Life-Cycle Costing in the Renewable Energy Debate." Renewable Energy 5(5-8): 1436-1443.
Henney, A. and G. Keers (1998). "Managing Total Corporate Electricity/Energy Market Risks." The Electricity Journal 11(8): 36-46.
Morris, G. (1999). "The Value of the Benefits of U.S. Biomass Power."
Wohlgemuth, N. (1999). "Cost benefit indicators associated with the integration of alternative energy sources: A systems approach for Carinthia, Austria." Renewable Energy 16(1-4): 1147-1150.

Environmental impacts. The extensive literature on environmental impacts and environmental externalities is probably most useful for its methodology and order of magnitude of quantitative effects, rather than as source of precise quantitative estimates. That's because the studies note that quantitative estimates depend heavily upon specific assumptions and locations. Sources include:

(1992). "US-EC Fuel Cycle Study: Background Document to the Approach and Issues." (Oak ridge National Laboratory and Resources for the Future).
(1994a). "Estimating Fuel Cycle Externalities: Analytical Methods and Issues." (report) (Oak Ridge National Laboratory and Resources for the Future).
Bernow, S. S. and D. B. Marrn (1990). "Valuation of Environmental Externalities for Energy planning and Operaions."
DeAngelis, M. and S. Rashkin (1989). "The social benefits and costs of electricity generation and end-use technologies."
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Pearce, D. W., C. Bann, et al. (1992). "The Social Costs of Fuel Cycles." (HMSO: Her Majesy's Statanary Office, Great Britain).
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Energy Efficiency and Distributed Generation. An extensive literature review data base on "Non-Energy Benefits of Distributed Energy" was prepared for DOE by BCS (2002). Effects of energy efficiency and distributed generation are also considered in sources such as:

Allison, J. E. and J. Lents (2002). "Encouraging distributed generation of power that improves air quality: can we have out cake and eat it too?" Energy Policy 30.
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Moscovitch, E. (1994). "DSM in the broader economy: The economic impacts of utility efficiency programs." Electricity Journal 7(4): 14-28.
Pye, M. and A. T. McKane (1999). "Enhancing shareholder value: Making a more compelling energy efficiency case to industry by quantifying non-energy benefits." (technical report).

Hedge Value. The value of diversification of fuel sources, or the hedge value against high natural gas price, has been quantified in sources such as:

Bolinger, M., R. Wiser, et al. (2002). "Quantifying the Value that Wind Power Provides as a Hedge Against Natural Gas Prices." (report).

Brower, M. C. (1997). "Gas-fired generation: Can renewable energy reduce fuel risk?" Fortnightly 135(9): 32-39.

Import Premium. The value of avoiding oil imports, including excess cost of oil due to the producers' monopoly and the direct and macroeconomic costs of oil price spikes.

Leiby, P., D.W. Jones, T. R. Curlee and R. Lee, 1997. *Oil Imports: An Assessment of Benefits and Costs*, Oak Ridge National Laboratory, Report ORNL-6851

Jobs and Other Local Benefits. Econometric studies to estimate local economic benefits of renewable energy projects include:

Bailey, A.; S. Bernow; W. Dougherty; M. Lazarus; S. Kartha; and M. Goldberg. (2001). "Clean Energy: Jobs for America's Future." Prepared for the World Wildlife Fund by Tellus Institute, Boston, Massachusetts.

Barrett, J., A. Hoerner, S. Bernow, and B. Dougherty (2002). "Clean Energy and Jobs: A Comprehensive Approach to Climate Change and the Environment" Report prepared for the Economic Policy Institute and the Center for a Sustainable Economy.

DynCorp EENSP, Inc (1995). "An Assessment of the Regional Economic and Employment Impacts of the Commercialization of Renewable Technologies in Florida and Indiana, Final Report." Prepared for the National Renewable Energy Laboratory by DynCorp EENSP, Inc, Alexandria, Virginia.

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Walter, J. (1999). "Greenpeace and Wind Industry Unveil Global Energy Blueprint" Greenpeace, Brussels, Belgium.

Wisconsin Energy Bureau (1994). "The Economic Impacts of Renewable Energy Use in Wisconsin." Wisconsin Energy Bureau, Madison, Wisconsin.